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BY
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L'Institut Météorologique Danois, qui est chargé de l'administration scientifique des travaux magnétiques terrestres en Danemark, publie dans sa publication « Magnetisk Årbog (Annuaire magnétique) » les observations régulières des trois observatoires magnétiques danois, savoir

Rude Skov $\lambda = 12^\circ 27'.4$ E, $\varphi = 55^\circ 50'.6$ N.
Godhavn $\lambda = 53^\circ 31'.3$ W, $\varphi = 69^\circ 14'.4$ N.
et *Thule* $\lambda = 69^\circ 10'$ W, $\varphi = 77^\circ 29'$ N.

En outre l'Institut réunit dans sa publication « Communications Magnétiques, etc. » les mémoires et les extraits des archives des trois observatoires qu'on juge utile de publier.

La série « Communications Magnétiques, etc. », paraît par occasion.

Karl Andersen
Directeur.

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L'INSTITUT MÉTÉOROLOGIQUE DANOIS
COMMUNICATIONS MAGNÉTIQUES, ETC. NO. 24

LOCAL AURORAE IN THE MORNING HOURS AT GODHAVN, GREENLAND.

Abstract:

A group of aurorae, occurring almost every clear morning near zenith at Godhavn, is described. It is assumed that these aurorae belong to an inner auroral zone, crossing Greenland from Godhavn to Danmarkshavn. The aurorae are correlated with the occurrence of sporadic ionospheric layers, but not with magnetic activity.

Introduction. In the period from January 1952 till April 1956 I made a visual study of the aurorae at Godhavn. In the first years my observations were concentrated about the occurrence of aurorae before midnight, aurorae after midnight being studied only occasionally. After a couple of years I thought that I had become so familiar with the behaviour of the evening-aurorae that I ought to pay more interest to the aurorae that occur late in the night and in the morning hours, and so I made a more regular study of these in the winters 1954/55 and 1955/56.

Before reporting these observations I have to mention the general scheme for the occurrence of aurorae at Godhavn.

Late in the afternoon auroral bands and arcs may be seen low in E and SE; in the evening hours a homogeneous arc may be visible in SE with maximum elevation not

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much above 10°, indicating that Godhavn is lying well inside the auroral zone. Sometimes the homogeneous band after an increase in intensity will suddenly disintegrate into raybands which will quickly travel towards zenith, sometimes passing it, after a time "freezening" into quiet diffuse forms, and after some time leaving pulsating forms of lower intensity. This is known from stations below and outside the auroral zone too, but there the aurorae are drifting southwards during the disturbance. This is both inside and outside the auroral zone accompanied by a magnetic bay. Though during the five winters I have seen a great number of aurorae of this type, I have never at Godhavn seen the flaming aurora.

After midnight the probability of getting such an auroral storm is diminishing, and from 1 - 2 hours after midnight generally only raybands near the horizon in SE to SW are seen.

Morning Aurorae. But in the early morning hours aurorae are again seen in the zenith at Godhavn. Whereas zenithal aurorae, when present in the evening hours, are connected with violent movements of rays and body movements of the bands, the aurorae in the morning give a very quiet and steady impression. Whereas the evening aurorae may be regarded as storm phenomena the quiet morning aurorae are present at all days. They consist of narrow diffuse bands through zenith from the NE to the southwestern horizon, sometimes with a faint ray- structure, or they are draperies - often several parallel draperies - of very long (say 40° long) rays - that may be in some distance from each other. Late in the morning, near dawn, from 6 - 7 o'clock till twilight, there have been so many long rays visible between W and SSW that one got the impression of standing in a narrow forest. The draperies will form fans and sometimes coronas, but these are more elongated in the direction of the draperies than in the evening hours, where the coronas are generally circular.

There may be some movement in the corona or fan, occasionally accompanied by colour effects, but generally the movements of the arcs are very moderate. They may sooner be described as pulsations of intensity; narrow homogeneous arcs may slowly die away, while parallel arcs a few degrees from them may grow in intensity. These slow pulsations may go on for a long time and may be one of the characteristic features of morning aurorae, but the pulsations seem quite irregular and not in phase in the different arcs or rays, so that the picture is only slowly shifting without essentially changing its mean position. The colour is grey-green; only when the intensity is very high, colour effects may be seen. Of a total of 108 mornings intensity 4 was observed on 8 mornings; in five of these cases colour effects were seen. The rays were then blue-green or white-green or they were red and green or yellow. I had seen these aurorae at several occasions in the early morning hours, and therefore in the winter 1954/55 I began a more regular watch in the morning and continued in this way in 1955/56.

As my observations were not part of the program of the observatory I was not able to keep a continuous auroral watch all night long. In fact I did so in a little number of clear nights in order to see, from where these aurorae came, but generally I had to use another procedure. Every morning before dawn I went outside my house to see the aurorae, and further I made observations when sometimes I happened to wake up in the night. In this manner I got observations every morning, but the observations were not made at a fixed hour, nor were they distributed at random within the early morning hours. This may to some extent have influenced some of the results of the statistics of the morning aurorae, which I am going to present now.

Frequency. The frequency of occurrence of morning aurorae was very high. Thus in 1954/55 aurorae were observed on 36 of 40 clear mornings (and might possibly have been seen at the four remaining mornings too, if there had been a continuous watch). In 1955/56 aurorae were observed on 70 of 70 clear mornings, and in a short series of observations in 1950/51 with fixed observation hour (8^h), aurorae were observed on 14 of 15 clear mornings. However, it must be mentioned that in the two winters 1954/55 and 1955/56 the observations were made with special care to secure that even very faint aurorae were noted. Less skilled or less interested observers might have lost a great part of the observations finding aurorae only when the intensity was rather high.

Elevation. The distances from zenith were measured with an accuracy of some degrees of arc by means of a simple auroral rake for several hundreds of arcs and draperies. The frequencies of occurence of different groups of distances are shown in figure 1. The histogram shows that the greater part of the arcs has been observed less than 5° from zenith. The frequency is falling off very steeply towards the north, more slowly towards the south. Thus, in mean, the aurorae are concentrated very near to Godhavn, with the greatest frequency a little to the south of zenith.

Several authors have suggested that the auroral zone is moving northwards in the course of night reaching its northernmost position in the morning hours. If the amplitude of this oscillation were sufficiently big the auroral zone might reach Godhavn from south in the early morning hours thus giving a plausible explanation of the presence of the Godhavn morning aurorae. Although quiet but folded raybands actually on a few occasions have been observed to reach zenith from a more southerly position, there are reasons to assume that this is an exception. In the first place, in the small number of nights when I was standing alert from shortly after midnight to study the first morning aurorae, these began as faint bands or draperies near the magnetic vertical being visible in very low intensity for less than a minute, lighting up again, possibly in a place a little different from the first one, and soon being followed by weak single rays in northeast and southwest and an arc through the zenith; after this time aurorae were visible at Godhavn until dawn, being more intense and in bigger number from about six o'clock.

Secondly, a subdivision of the histogram for the zenithal distances into histograms corresponding to each hour of the morning (Fig. 2) shows that, although it is hardly statistically allowed to draw definite conclusions about little displacements of the distributions, it may be concluded that a shift of the zone as great as would be expected if the aurorae were part of the usual auroral zone has, not been observed.

Further, aurorae are known to be present at the same hours at stations in the immediate neighbourhood of the auroral zone, and it is therefore believed that the morning aurorae at Godhavn are local, occurring well inside the auroral zone only.

Inner auroral zone. The Danish Meteorological Institute has in its archieves a number of auroral observations made by climatologic observers. A study of this material has shown that aurorae of a type similar to that described already have been observed in the morning hours from a number of stations at the western coast of Greenland. Further they have been found at Danmarkshavn in North-East-Greenland (1, 2, 3), where they are reported to stand near zenith. I have not finished the search for more stations with the same type of aurorae, but I think that the material already present is suggesting that we are studying an inner auroral zone, hitherto neglected, and only active in the morning- and day-hours. Fig. 3 shows a map of Greenland where stations with morning aurorae in zenith are represented by an open circle. Other stations (climate stations) with morning aurorae are represented by a point. The suggested zone is drawn dotted.

Direction of arcs. Professor Alfvén has shown that the direction of the arcs in the morning hours is of special interest (4). The directions of nearly fifty arcs with a distance from the zenith of less than 30° have been plotted as a function of the hour (Fig. 4). From the first aurorae have been observed at a little before two o'clock till about 6^h the arcs are nearly perpendicular to the direction of H. Between 6^h and 7^h the direction is quickly shifting possibly to a maximum at about seven, then decreasing a little again. The time is 45° w. t.; half an hour must be subtracted to get Godhavn local time. The accuracy is not sufficient to state whether there is a gradual variation of the directions between 6 and 7 or a discontinuous rise of about 20° in the curve at about 6 1/2 e. g. 6 o'clock local time, as claimed by Alfvén's theory.

Disturbance of Ionosphere. The ionosphere over Godhavn is very disturbed at the time when the morning aurorae are present. The disturbances are of a characteristic class; at about 2 - 3 o'clock the F-layer is dissolved into spread F and oblique incidences, which are quickly accompanied by sporadic E-layers of auroral type in different virtual heights between E- and F-layer height. The sporadic layers have in one case been found to begin at the same time as the visible auroras; further studies of the correlation of the start times of the two phenomena have not been possible yet on account of missing ionospheric material, but there seems to be little doubt that the disturbances of the ionosphere are closely related to the morning aurorae. Also, it has been found that great intensity of the aurorae is accompanied by great ionozation.

Therefore I have used ionospheric results to a couple of studies which could not be done with the existing auroral material. In the publication series CRPL from the National Bureau of Standards is given the mean daily distribution of the frequency of $E_s > 3$ Mc/sec. The distribution is published month by month. By combining the hours from 3 to 8 of the years 1952 - 56 I have found the mean curve for the distribution of the ionozation (Fig. 5). The variation is a single wawe with maximum at midwinter and minimum at midsummer, that is a variation of the same type as we have for the ordinary auroral observations at the polar side of the auroral zone.

Sunspot variation. Next, the percentage of morning hours with $E_s > 3$Mc/sec was plotted against the sunspot-number. The percentage varied from about 35 % in the autumn of 1951 through 40% in the spring 1954 to about 8% in the summer of 1957. Thus the ionization seems to vary opposite to the sunspot number, a result that would be consistent with the variation of evening aurorae at Godthåb, found by Tromholt.(5)

As the ionospheric results covered slightly more than half a sunspot period, only, I began to search for further material. In the years 1923 - 37 aurorae had frequently been noted in the lists of climatologic observations made at Godhavn by one of the inhabitants for the Danish Meteorological Institute. Taking the observations at 8 in the morning in December and January and plotting the percentage of clear mornings with aurorae against the year I got a relation quite contradictory to the ionospheric one, the percentage rising from 1923 to about 1930, then probably falling off again.

It was necessary to have more material, and fortunately I happened to find a series of climatologic observations with notes about aurorae from Jakobshavn, a settlement some hundred kilometers east of Godhavn, covering the period 1875 - 1915. Further, from 1887 - 1914 the observations were made by the same observer. The description clearly showed that the aurorae in the morning were the same as those seen from Godhavn. Again the percentages of clear mornings with aurorae were plotted as a function of the year. The resulting curve is shown in Figure 6, where a special signature has been given to the observations made by one and the same observer.

It is seen that aurorae were frequently seen in the years around the sunspot maxima 1884 and 1906, whereas they were seldom noted in the years around the maximum in 1893. In fact the observations indicate a variation in a 22 year period, that is to say a complete sunspot cycle. This is both consistent with the results from the climatologic observations at Godhavn, which indicate a maximum shortly after the sunspot maximum in 1928, and with the ionospheric results, which show a minimum at the present sunspot maximum. In my own observations from Godhavn I found aurorae on practically all clear mornings in the recent years. This may not be in disagreement with the found results, as I took special care to find the faint aurorae, whereas a climatologic observer is likely to note aurorae only when they are marked.

Magnetic disturbance. Whereas the aurorae in the evening hours are usually accompanied by magnetic disturbances, the morning aurorae very seldom give rise to measurable magnetic effects. Generally, the magnetic perturbations seem to be completely uncorrelated with the presence or variation of aurorae. Even in four of the eight mornings with observed high intensity and colour-effects it was impossible to find any correlation with the variations of the magnetic field. In those few cases in which a correlation seems to exist the intensity and activity of the aurorae are big and with colour effects.

It has been shown by Stagg (6), after the Second International Polar Year, that the daily distribution of magnetic activity at Godhavn has an evening- and a forenoon-maximum. The evening activity is related to auroral storms; it has hitherto been assumed that the forenoon maximum of geomagnetic activity was related to the morning maximum of auroral activity, so that it could be concluded that the auroral maximum actually should be placed in the forenoon, but is not observed because of daylight. The conclusion can be found in Chapmann-Bartels (7) in the description of the aurorae at Cape Denison in the

Antarctic. The conclusion can not be correct, however, at least for Godhavn and similar stations, because: a) there is no correlation between morning aurorae and magnetic perturbation, b) the morning aurorae have a yearly distribution with a maximum in midwinter, whereas the magnetic morning activity is known to vary as a single wave with maximum at summer solstice (8), c) the magnetic morning activity follows the sunspot number, whereas the aurorae seem to vary with the double period, d) it has been reported by Nicholsky (9) that at the observatory Calm Bay the magnetic morning disturbance is present without any aurorae or ionospheric perturbations.

Further knowledge about the hour of maximum auroral activity should therefore be sought partly in auroral observations at stations with a dark forenoon in winter, partly in ionospheric soundings. As to the first the climatologic station at Upernavik has a few times noted auroras at 14 o'clock around midwinter, but it is not known yet whether these belong to the class of aurorae seen in the morning at Godhavn. The same must be said about the aurorae recorded with All-Sky Camera at Station Nord in the IGY at different times of the day, and even at noon; here it will presumably be possible to get some information about the type of aurorae, but as Station Nord is lying well inside the maximum-zone of morning-aurorae the number of occurrences will possibly be too small for statistics. The ionospheric method is rather difficult on account of interference with other disturbance as black-outs and has not been studied in detail yet.

Later results from the study of the inner auroral zone are being published in NATURE.

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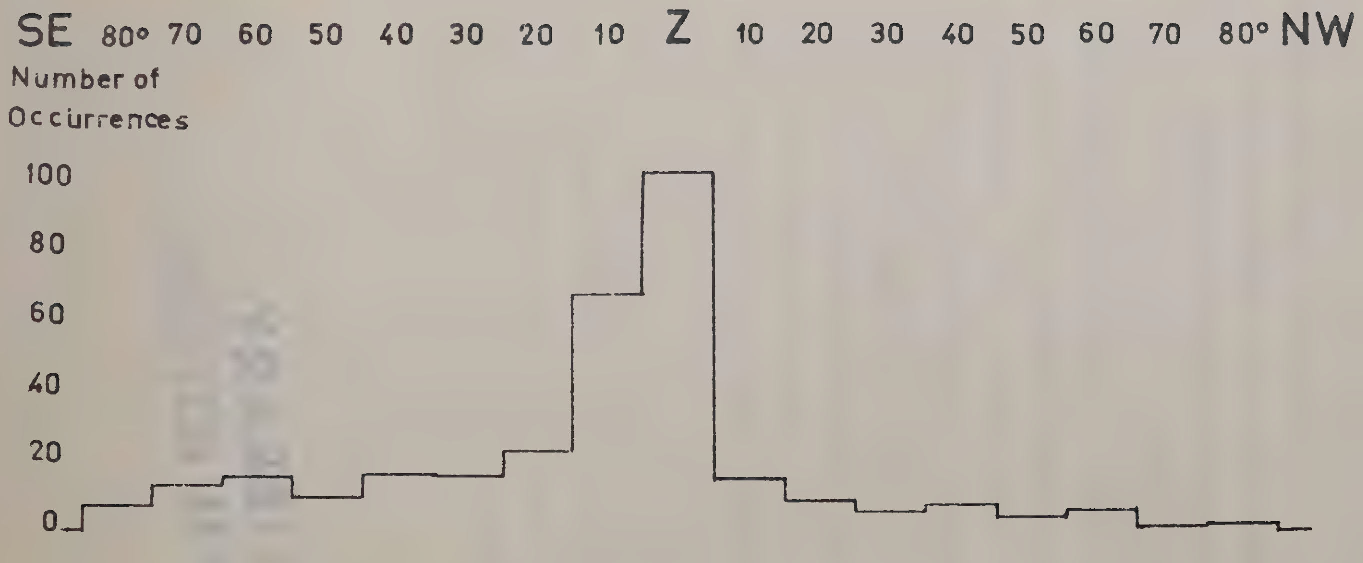
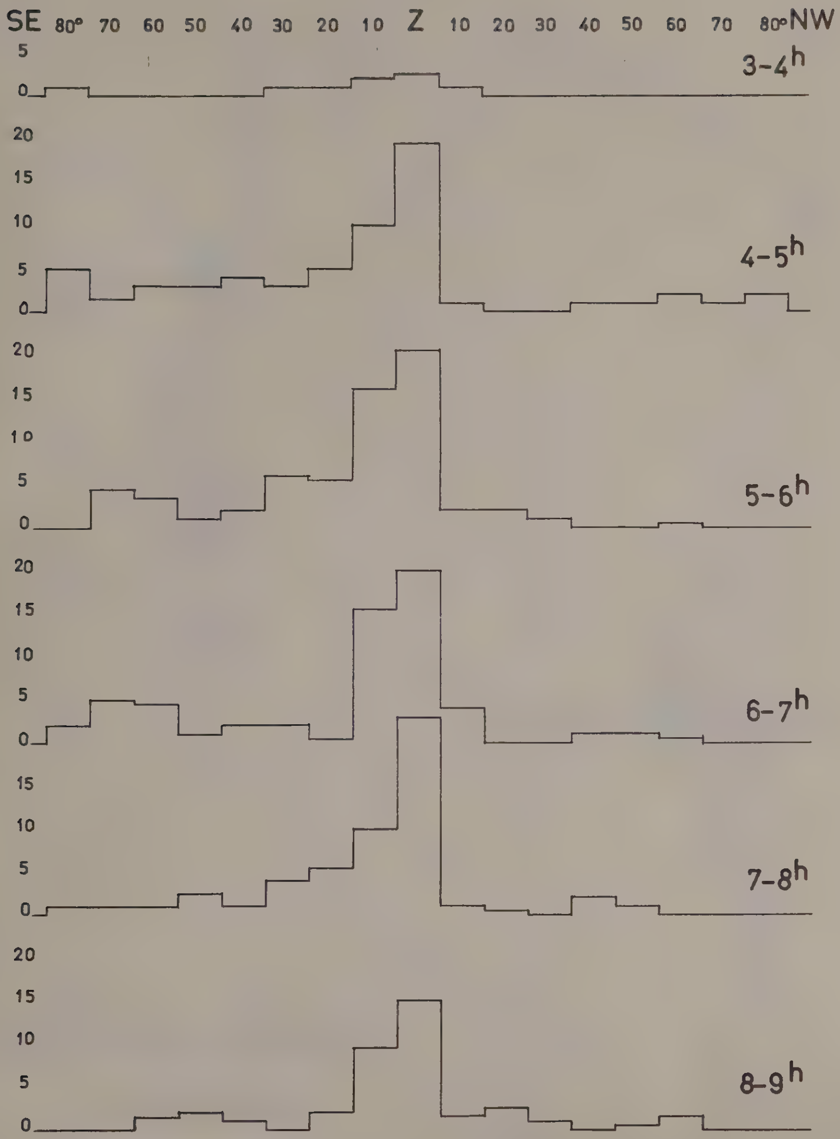


Frequency-Distribution of Zenith-Distances
Godhavn 1954-56

Fig. 1



Number Occurrences Different Zenithdistances, Hourly Distributions.
Godhavn 1954-56

Fig. 2

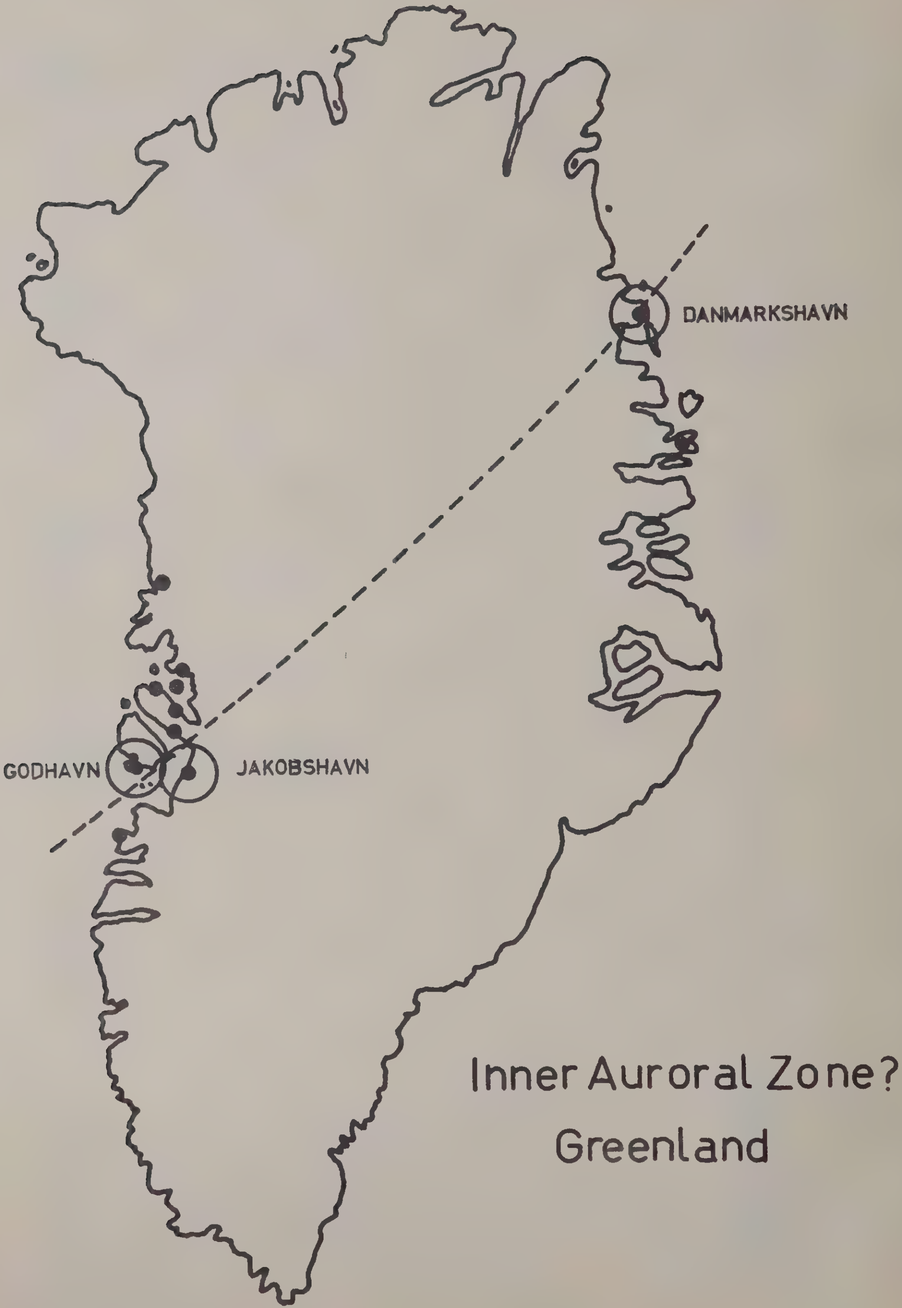
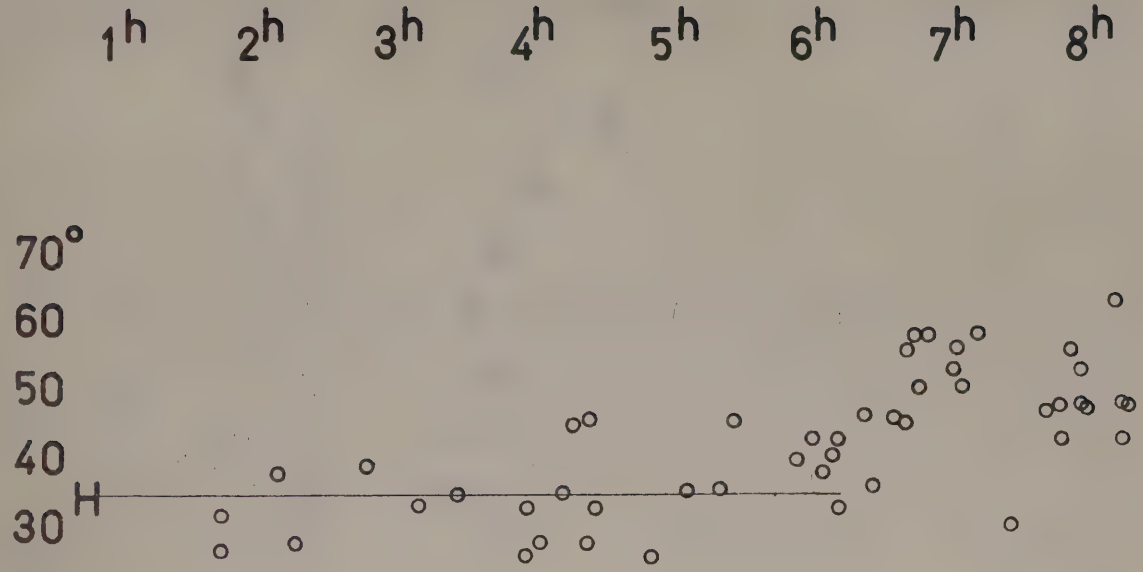

DANMARKSHAVN
GODHAVN
JAKOBSHAVN
Inner Auroral Zone?
Greenland

Fig. 1



Azimuth of arcs, Godhavn 1954–56

Fig. 4

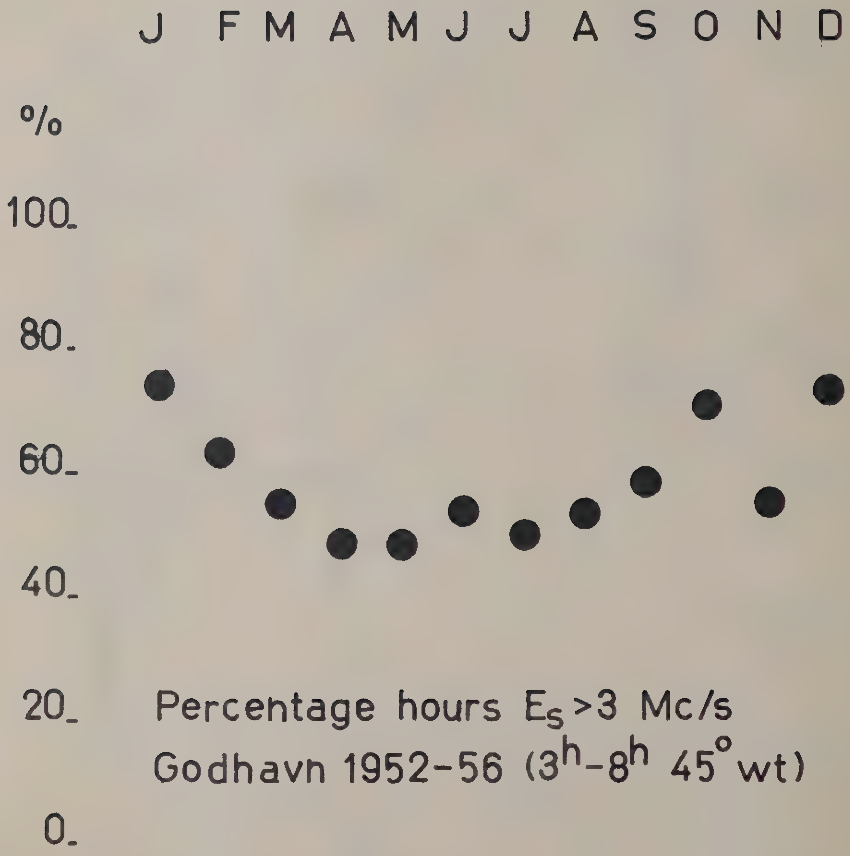
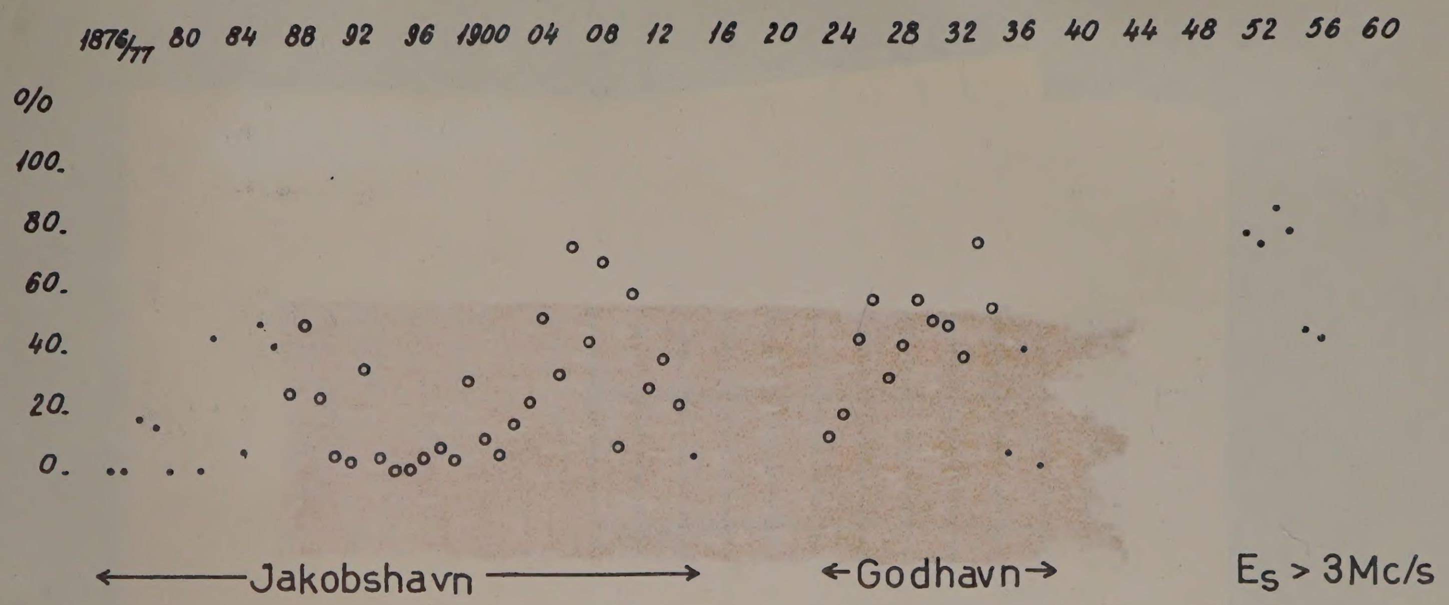

J F M A M J J A S O N D
%
100
80
60
40
20
0
Percentage hours E_S >3 Mc/s
Godhavn 1952-56 (3^h-8^h 45° wt)

Fig. 5



Relative frequency of morning auroras 1875/76-1956/57

Fig. 6

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Local aurorae in the morning hours

AUTHOR

at Godhavn.

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